Mr. Raymond Binford, Johns Hopkins University, continued the study of the life histories of the crabs of Beaufort, especially that of *Menippe mercenaria*. By a later study of the material killed and preserved during the summer, the processes of fertilization and gastrulation in this crab are being worked out.

In experiments in which eggs were subjected to differences of temperature, those which were kept a few degrees above normal hatched nine days after they were fertilized, while those kept below the normal hatched on the thirteenth day after fertilization.

Some twelve hundred of these crabs were caught in the waters about the Beaufort harbor during the summer.

Mr. J. D. Ives, instructor in biology, Wake Forest College, made observations on the regeneration of nemerteans and *Amphitrite* during the month of August. Sections of nemerteans were found to regenerate readily. The anterior surfaces of the sections were found to regenerate but a small amount of new material compared with that formed by the posterior surfaces. The posterior surfaces of the sections regenerated rapidly. In about four weeks, sections of worms not over one half inch long were found to more than double their length with new material.

The tentacles of *Amphitrite* when pulled off were found to regenerate readily. In about ten days or two weeks after removal, the tentacles attained nearly an inch or about half of their normal length. When the entire tentacle bearing somite is cut off, the worm lives almost as well as when only the tentacles are removed. When the somites bearing both the tentacles and the first pair of branchiæ were cut off, some few specimens lived for over two weeks.

HENRY D. ALLER

THE BIOLOGICAL EFFECTS OF RADIUM[1]

AMONG the first discoveries made after the production of concentrated radium salts was that radium is capable of causing intense effects upon living tissues. We were not unprepared for such a discovery in the case of radium because similar phenomena had been observed early in the study of X-rays. In the case of X-rays the discovery had been totally, and very unfortunately, unexpected. The early burns from radium were of the same character as X-ray burns, and later detailed study has shown that the effects upon tissues of the two agents are practically identical. An appreciation of this fact is useful at the outset of a consideration of the biological effects of radium; it gives one at once a large number of analogous facts that have been well studied and, because of the more extensive study that has been made of the biological effects of X-rays, enables one to correlate more satisfactorily some of the isolated observations upon the actions of radium. Because the gross effects of radium, which furnish us many valuable facts, can be studed in the skin, and because the effects upon the various tissues of the skin give us the most comprehensive view of the biological effects in general of radium, it is conducive to clearness to consider first the effects of radium upon the skin, meaning by the skin in this connection the human skin or skin of similar structure of other animals.

When the human skin is exposed for a sufficient length of time to an active radium salt a peculiar and definite reaction is set up, of which the first striking feature is that it does not develop until after a relatively long period of quiescence—as a rule about two weeks. In a skin containing a considerable amount of pigment, there is first an increase of pigment, shown by an ordinary "tanning" of the exposed surfaces. If there are any freckles or pigmented spots in the exposed area, these become darker. Along with this pigment stimulation there occurs a reddening of the skin, with a feeling of irritation and burning such as one has from sunburn. The reaction may stop at this point and after a few days gradually subside; the redness and irritation diminish, there is some scaling from the surface and in a few days more no evidence of the reaction remains,

[1] Address before the Illinois State Academy of Science, Chicago, February 18, 1911.

except the increased pigmentation which is very slow to disappear.

In this reaction we have had simply the familiar picture of sunburn. But the process, in many cases, goes much further, and then there occurs a reaction which is peculiar to X-rays and radium. After the development of an inflamed, reddened area of skin the surface becomes intensely congested, purplish, and then blisters form. At the same time, or before, the hairs loosen and fall out. Next the blisters rupture and leave a surface covered by a necrotic pellicle, like a diphtheria membrane. And the reaction may go still further, with the formation of an ulcer whose striking characteristics are its painfulness and its extreme indolence, showing, it may be for months, no tendency to regeneration. The process may stop at any of the stages described above. If subsidence occurs short of ulceration the skin may again become normal, but after the severe reactions without ulceration, and after ulceration, when healing takes place there may be very distinct permanent changes in the skin. The hairs grow sparsely or not at all; the pores are very fine or absent, from destruction of the glands of the skin. The skin is thinned, with here and there roughened horny points or patches up to the size of a finger nail, and the surface is reddened from numerous dilated capillaries which show through the thinned horny epidermis.

We have here, as a result of these powerful forms of radiant energy, a picture of extreme interest. The condition is in fact an exact, sometimes an exaggerated, picture of the atrophic senile skin, with its dilated blood vessels and senile keratoses. As a matter of fact the picture is so nearly that of senile skin that I was able, in the case of X-ray lesions, to predict that cancers of the skin would be found to develop in them because the keratoses of old age are so frequently the starting point of cancers. It would take us too far from our subject to give all of the reasons for the idea, but the identity of chronic radium and X-ray changes in the skin with those of the senile skin, strongly indicate that the senile changes of the skin are in good part the result of the less powerful action over a long period of years of sunlight. Another fact, that is beside our topic, is highly interesting in this connection: Cancers develop in the keratoses of X-ray and radium dermatitis, and in them we have one form of carcinoma which is directly traceable to its exciting cause; and only by bringing in a *deus ex machina* in the form of later infection can one avoid the conclusions that at least in these lesions we have cancer which is not of microbic origin.

When radium is applied to various pathological lesions in the skin the same phenomena occur that are seen in healthy skin, with the addition that under proper precautions selective destructive effects may be produced upon the diseased tissues. Take, for illustration, nodules of tuberculosis or of carcinoma or sarcoma (cancers) in the skin. With proper care in grading the applications a reaction may be produced which will cause these tissues to be entirely destroyed, while this reaction is not sufficient to destroy the normal stroma in which they are situated, or, if it does destroy the normal tissues in the involved area, they will regenerate with the formation of healthy scars. It is also found in itching and painful conditions of the skin that the applications have a definite anesthetic effect.

The microscopic changes in tissues undergoing a radium reaction are even more interesting than the gross changes. In the early stages of radium irritation sections show evidences of proliferation of the tissue elements, such as indicate an over-stimulation of the cells by a peculiar irritant. These changes are most marked in the tissues of the greatest functional activity. At first there are an increased production of pigment, and an exaggerated proliferation of the germinal and younger (deeper) cells of the epidermis, especially of the cells of the follicles of the epidermis; in the corium or body of the skin, there are dilatation of the capillaries, an infiltration of round cells, and œdema—the changes of inflammation. Later the changes become exaggerated: there is proliferation of the inner layer of the blood vessels (an ob-

literating endarteritis); the round-cell infiltration becomes intense; the connective tissue fibers are œdematous and stain poorly. In the epidermis the cells show extreme degenerative changes; they become vacuolated, the nuclei are fragmented, there is degeneration of the cytoplasm so that stains are taken poorly, and complete breaking down of many cells. These changes are especially intense in the highly specialized and active cells of the appendages of the skin—the hair follicles and the sweat and sebaceous glands—and they may result in the obliteration of these structures, a phenomenon which, occurring as it may without destruction of the surrounding tissues, is not produced by any other known agent. In the last stage in a radium reaction there is necrosis of all of the affected tissues, the connective tissue stroma being the most resistant and last to break down. In diseased tissue of the skin such as epithelioma (cancer) and lupus (tuberculosis), there is the same sort of reaction; it is also found that the pathological tissues which are composed of growing cells, often of embryonic type, react in the same way as the active sensitive tissues of the normal skin. They are more sensitive to the effects than the stroma in which they are growing, disintegrate or degenerate readily, and are destroyed before or without destruction of the connective tissue around them.

It is evident in this process that we are dealing with an agent whose results are produced by influencing the biological processes of the cells themselves. The effects are not produced by an immediate destructive action of the rays, as a heat burn, for example, is produced. There is no immediate effect from the application of radium; it is only after days, it may be two or three weeks, that the effects appear. The inference is that the radiations set up some process in the tissues which itself ends in their destruction. The whole process is one of exaggerated stimulation of the activity of the cells of the tissues: a stimulation which varies in degrees with the degree of specialization or functional activity of the different type of cells. In its slightest degrees it is the ordinary protective process that occurs under exposure to sunlight, but under the unusual and extreme irritation of this artificial form of radiant energy the reaction becomes destructive.

Since the effects of radium have had therapeutic application, it may be interesting to pause to consider briefly this aspect of the subject.

As I have suggested, the effects of radium to a degree are selective in that they excite the intensest reaction in the cells of great functional activity whether this be in the exercise of a special function or the simpler function of growth. Thus there is produced by radium: (1) A stimulation of the cells; (2) an exaggerated effect upon the highly specialized structures of the epidermis, viz., the hair follicles, and the sebaceous and sweat glands, and likewise upon the basal or germinal layer; (3) an endarteritis or proliferation of the lining membrane of the blood vessels which may lead to obliteration of many blood vessels; (4) destruction of masses of diseased tissues, which are composed of young growing cells or immature cells.

These effects upon tissues suggest the possible use of radium for various therapeutic purposes, as follows: (1) To stimulate chronic processes. This principle has been successfully used in the treatment of some chronic inflammatory processes in the skin. (2) To destroy or diminish the follicles of the skin, particularly the hair follicles. This principle has had practical application with X-rays, but because of the small quantities available, not with radium, except in the case of hairy nævi (birthmarks). (3) To obliterate blood vessels in the skin. This has had practical application, with very successful results, in the treatment of vascular nævi (birthmarks). (4) To destroy pathological tissues. This use is of course possible of wide application, and has been successful in various diseases of the skin and the adjacent underlying structure, especially in carcinomas and sarcomas (cancers). Its limitation in cancer is that it is only effective upon such

lesions as can be directly exposed. As the action is to a degree selective, radium and X-rays have had very valuable practical uses in these diseases. (5) Finally the anodyne effect of radium has had some application in the relief of itching and of pain.

The therapeutic uses of radium are obtained from the above indications. The indications which might seem to be derived from the effect upon other organisms, especially upon bacteria, yet to be considered, have not increased the practical application of the agent.

Experiments upon other mammals have added little to the facts given above. Experiments on rabbits have shown that exposure to the radiations causes anesthesia in peripheral nerves (Beck), confirming a fact established by clinical experience. Danysz and Bohn have shown that the nervous system of certain young animals is peculiarly sensitive to the effects of radium, exposures so arranged as to reach strongly the cerebro-spinal axis causing paresis, ataxia, convulsions and death. These phenomena, with negative controls, were elicited in mice, which proved most sensitive, and in guinea pigs and rabbits. The sensibility is very much greater in the very young animals, persists in older mice, but disappears in great degree in adult guinea pigs and rabbits. Similar effects upon the nervous system of man from either radium or X-rays do not occur.

I can not take more than enough time to refer very briefly to the effects of radium upon micro-organisms, upon development and upon plants. The knowledge upon these subjects has been carefully summarized in a paper by Hussakof, of Columbia University, which is readily available.

Several experiments have shown the inhibitive or, under stronger exposures, destructive, effect of radium rays upon various bacteria in cultures—the bacillus prodigiosus, colon bacillus, typhoid bacillus, anthrax bacillus and the spirillum of cholera. These are the only biological findings differing from those with X-rays, and are probably due to the greater superficial effect of the alpha and beta rays because of their very slight penetration as compared with the softest X-rays. They indicate a close similarity, with a difference chiefly in degree, in their biological effects between alpha and soft beta rays and ultra-violet rays.

Similar results have been obtained by several observers from exposures of numerous forms of protozoa. Their growth is at first stimulated, then inhibited, and after intense exposures they are destroyed.

Experiments on various eggs, embryos and larvæ have shown, as would be expected, in these embryonic tissues, a high degree of susceptibility. Growth is retarded, monstrosities develop, and, from prolonged exposure, death occurs.

In plants the results of experiments may be summarized briefly as first stimulation of growth, and under stronger application, retardation or complete inhibition of growth.

This consideration has been directed to the effects of radium rays. As to the emanations, it may be stated briefly that experiments with the emanations upon young mice, upon bacteria, and upon protozoa show results quite like those from exposure to the rays.

There is apparently no difference in kind in the effects upon tissues between the different radium rays. Alpha rays have so little penetration that their effect is expended entirely upon the most superficial tissues, but when they are screened out the only difference in the reaction is one of intensity and depth. Exner, in a repeated experiment, by deflecting the beta rays with an electro-magnet directed them upon one white mouse while the gamma rays fell upon another mouse equidistant from the radium. Fifteen days after exposure, which had been for 18⅔ hours, a similar ulceration appeared on the tails—the exposed areas—in both mice. All three forms of radium rays then, are physiologically active. This fact might fairly be inferred from their actinic properties. For the physiological effects of all forms of radiant energy, there seems every reason to

believe, are a manifestation of the same actinic effects that we have long been familiar with in certain inorganic substances. Indeed, beginning with the red rays of light at one end of the scale and ending with the hardest X-rays and gamma rays at the other, we find physiological effects differing chiefly in degree and corresponding in intensity with the actinic strength of the respective rays.

What the bio-chemical processes are that are set going by radium, or by the more familiar forms of actinic energy, we are in no position to say. From experiments with radium upon eggs Schwartz proposed that all of the effects of radium upon tissues were due to decomposition of lecithin. Hussakof suggests from experiments of Willcock, Zuelzer and Körnicke that oxygen in some not understood way seems to play a part in the process. There is every reason to believe that the process is not explicable by any simple chemical reaction. Radium rays do not produce an immediate effect upon living tissues, similar to the reduction of silver salts, for example. They have an effect upon the life processes of the cells, and these after a relatively long time produce the results that we recognize as a radium reaction. In other words the process is a vital process, and one, doubtless, involving all of the chemical complexity of cell life itself.

BIBLIOGRAPHY

HUSSAKOF, LOUIS. *Medical Record,* July 20, 1907. Action of radium on plants and animals (full summary and bibliography).

HALKIN. *Archiv f. Dermat. und Syph.,* 1903, LXV., p. 201 (histology).

DOMINICI and BARCAT. "Archives des Maladies du cœur, des vaiseux et du sang, 1908" (histology).

DOMINICI. *Archives Générales de Médicine,* July, 1909 (histology).

GUILLEMONT. "Archives of the Röntgen Ray," Vol. XV., No. 3, August, 1910. (Effects on seeds and plants and biochemistry.)

BARLING. *Brit. Med. Jour.,* July 30, 1910 (histological effects on malignant growths).

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SPECIAL ARTICLES

ON THE CLASSIFICATION OF SAND GRAINS

PROFESSOR W. H. SHERZER has just published an important paper containing a classification of sands[1] in which a successful attempt is made to use origin as the primary factor for determining subdivisions. I say successful, because I believe Sherzer's classification to be a sound one for the reason that it is a natural one. In detail, as he himself says, it requires further amplification, but I believe that its leading features will stand. He distinguishes the following types: (1) *Glacial sand type,* (2) *volcanic sand type,* (3) *residual sand type,* (4) *aqueous sand type,* (5) *œolian sand type,* (7) *organic sand type,* (8) *concentration sand type.* The first five of these are clastic, the others are non-clastic. To the clastic he might have added as number 6 the artificially produced sands (or mechanico-organic) which no classification can afford to neglect, and to the non-clastic might be added, for completeness sake, (9) the granular snow and the firn or nevé, precipitated from the atmosphere, and (10) lapilli of igneous origin, but not pyroclastic. With the glacial sand group (1) Sherzer compares those formed by avalanches and rock slides, by rock and mud flows, and by earth movements along joint planes, *i. e.,* the familiar fault sand. He also adds the sand produced in the manufacture of talus, but this, when not due to mechanical slipping, clearly belongs under his residual type.

As thus included, the mechanical abrasion sands: glacial, fault, etc., come under the heading of *autoclastic sands,* and the series given by Sherzer, with the addition of the artificial sands, corresponds exactly to subdivisions of clastic rocks which I published in 1904,[2] as shown in the following table, where the corresponding divisions of my

[1] W. H. Sherzer, "Criteria for the Recognition of the Various Types of Sandgrains," *Bull. Geol. Soc. America,* Vol. 21, No. 4, pp. 625–662, pls. 43–47.

[2] A. W. Grabau, "On the Classification of Sedimentary Rocks," *American Geologist,* Vol. 23, pp. 228–247, April, 1904.